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FIG SMUT

BY

EDITH H. PHILLIPS, ELIZABETH H. SMITH AND RALPH E. SMITH

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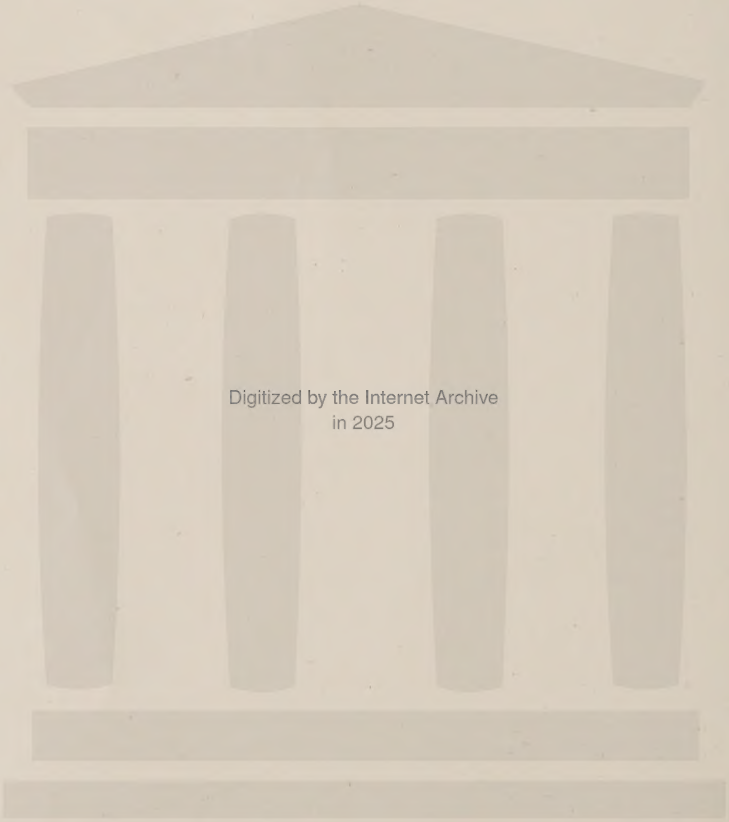

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By EDITH H. PHILLIPS, ELIZABETH H. SMITH AND RALPH E. SMITH

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THE PROBLEM

NATURAL ADVANTAGES OF THE FIG INDUSTRY

The fig deserves to be one of California's best commercial fruits. It shares with the olive and grape the distinction of being one of the oldest cultivated fruits. It is nutritious, appetizing, of attractive appearance and wholesome. The fruit has a great variety of uses, not only in the usual dried form, but also for eating fresh and in such manufactured forms as jam, marmalades, preserves, canning, candy, bakery products, breakfast and health foods, beverages and medicinal preparations. The well known salutary properties of dried figs lend themselves particularly well to advertising. The fig is one of the healthiest of fruit trees, easily suited as to soil and moisture, and well adapted to a wide area in California and (for dried figs) to no other portion of the United States. The quality of California-grown figs at their best is admittedly unsurpassed.

And yet, it must be said that fig culture is not so well established in California as that of many other fruits and considerable difficulty is experienced in disposing of the comparatively small dried fig crop of the state at even moderate prices. California produces less than 10,000 tons of dried figs per annum (9000 tons in 1923) as compared with 25,000 tons of walnuts, 100,000 tons of prunes, and 250,000 tons of raisins. Even though foreign competition is keen, exchange rates low, and fig production in the Mediterranean countries very large, it seems remarkable that this small tonnage of California-grown figs cannot readily be marketed at good prices.

WHAT IS THE MATTER WITH FIGS

The greatest obstacle to the success of the fig industry at the present time is the occurrence of various forms of rotting, souring, and molding of the fruit, which at times become very abundant and troublesome and for which no method of control has been found. Such defects reduce yields and make it very difficult to put up a high-grade, dependable pack of sufficient quality to compete on better than even terms with the foreign product and one upon which the arts of advertising and salesmanship can confidently be practiced. It is only by such advertising, backed by superior, uniform quality that our increased production of other foreign-competing fruit products has been successfully marketed.

HISTORY AND PURPOSE OF THIS INVESTIGATION

Soon after the formation of the coöperative fig marketing organization, "The California Fig Growers" (afterwards merged into the "California Peach and Fig Growers, Inc."), the directors of the association felt that more information about the nature and control of these troubles was urgently needed for the welfare of the industry. The disease called "smut" first attracted attention on account of its conspicuous nature. The senior writer was accordingly employed by the Association in December, 1920, to investigate this problem. The first year's work was at the expense of the Association. After December, 1921, the investigation was supported by the Agricultural Experiment Station of the University of California, with the coöperation of the Association. This work was done mainly at Fresno, California, and in the Plant Pathology laboratory at Berkeley.

Credit is due to many fig growers and others for assisting in this work. Particular mention must be made of Mr. I. J. Condit of the California Peach and Fig Growers, who has been of constant aid in carrying out the experiments, and who also furnished several of the illustrations. Messrs. Markarian of the Markarian Fig Gardens, Fresno, and Glotzbach of the Burleigh Ranch near Fresno, offered to the writers every facility for work in their orchards, and a large part of the work reported in this bulletin was done in these two places. The assistance and coöperation rendered by many other growers is hereby gratefully acknowledged.

PECULIARITIES AND VARIETIES OF THE FIG

The fruit of the fig is an enlarged, hollow receptacle or flower base, with a small opening at the apical end. The little individual flowers are borne closely crowded together on the inner surface. Figure 7 gives a good idea of this structure. When fertile seed are produced, pollination is effected only through the agency of the *Blastophaga* insects, which bring the pollen from the staminiferous, non-edible Caprifigs in which they breed. Some varieties of figs set no fruit without such pollination, while other kinds produce abundant fruit without pollination but contain no fertile seeds. The word *caprification* is commonly used to designate the process of pollination effected by the insect. If caprification happens to take place in those varieties which

do not require it, the figs contain fertile seeds and have a somewhat different character from the uncaprified specimens. From the standpoint of disease, important variations exist in the structure of the fruit in different varieties of figs, relating especially to the size of the terminal opening and that of the interior cavity. Of the many different fig varieties, four are commonly grown in the San Joaquin Valley of California. The Calimyrna is the true Smyrna type of fig, requiring caprification. The Adriatic is a white, non-caprified variety grown extensively for drying. The Mission is a black, non-caprified fig used for both fresh and dried fruit, and noted for the vigor and hardiness of the tree. The Kadota (which is properly the Italian variety Dotatto) is a small, white, non-caprified fig grown especially for preserving. The fruit of the Mission and Kadota has a solid center with little interior cavity and a small, closed eye, while in the Calimyrna and Adriatic the eye and (in the Adriatic) the inside cavity are rather open. The importance of these differences will appear later in connection with the relation of insects to fig smut and other diseases.

WHAT IS FIG SMUT

Typical smut in dried figs occurs as a black, powdery mass in the pulp of the fruit (fig. 1, A). The mass is composed of fungous spores. On squeezing such fruits the spores shoot out for a considerable distance from the eye in a black cloud, while fruits less affected show dark or yellowish spots in the pulp with no spores. The skin of many of the badly smutted figs has a dark, translucent appearance by which they are easily picked out, but others, especially those with pulp only slightly affected, show no external evidence of disease, and so reach the market. It is only on tearing open such figs that the smut is discovered. Tests have shown that smutty figs are not injurious when eaten, but the appearance of such figs is disgusting and the finding of one in a package is often enough to cause the whole lot to be thrown away and the purchaser to hesitate before again buying California dried figs. The discovery of a smutty fig in the preserved, fresh fruit by cutting into it with a spoon and seeing the inky contents run out into the clear syrup, is even more disgusting. This has a serious effect on consumption, although the number of smutty figs occurring either in packages of the dried fruit or in the preserved products is extremely small and the actual loss of material is insignificant.

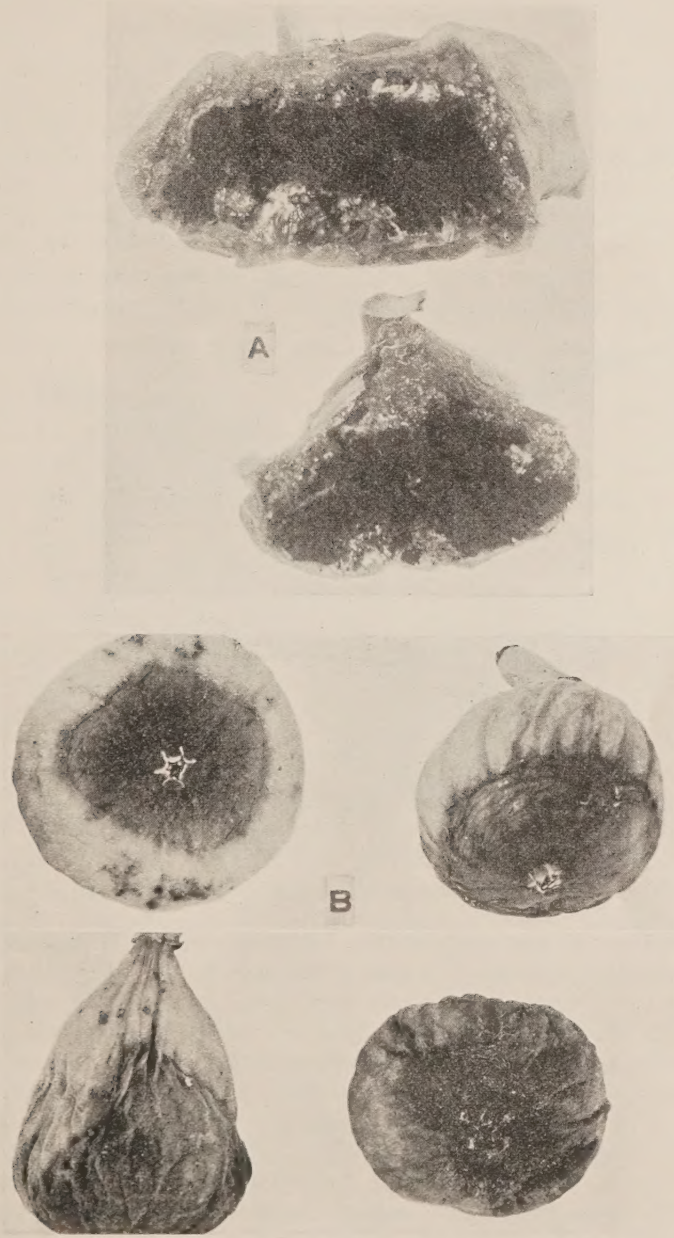

Fig. 1.—Fig Smut. (A) Interior, mature fig. (B) Exterior fresh figs on tree.

OCCURRENCE OF SMUT

As is well known to growers smut may be found in figs in the drying yard and even while they are still hanging on the tree. In such places there is sometimes a considerable percentage of affected fruit, particularly in the first pickings. Many of the smutty figs can quite readily be thrown out when they are gathered from the ground. They are, however, mixed with culls of various other kinds more numerous than the smutty specimens. While the smut-affected figs

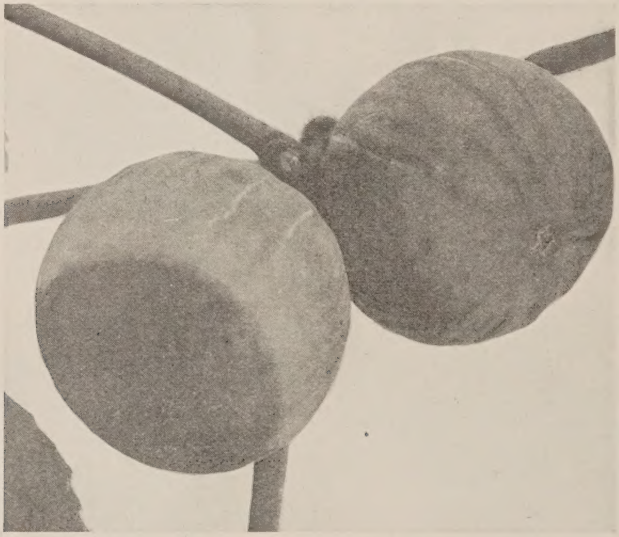

Fig. 2.—Fresh fig, with rot caused by smut fungus.

are still on the tree, some of them can quite easily be detected by the discoloration and soft rot at the eye end (fig. 1 B, and fig. 2). Others cannot be distinguished from the good figs without breaking them open.

The effect of the disease on fresh figs is very characteristic. Both skin and pulp are affected, starting round the eye. The color is dirty white or slighly pinkish, the texture fairly firm, stiffening and thickening up somewhat to a cheesy consistency. The surface of the skin is clean except in rare cases of contacts, but a mass of white mycelium develops in the pulp with final formation of pockets lined with the characteristic black spore masses. In late infections the spores are formed earlier and the pulp only is affected, which accounts for the difficulty in eliminating all of the smutted figs during sorting.

VARIETIES AFFECTED

No kind of fig is entirely immune to smut, but the Black Mission and Kadota varieties are much less affected than the Adriatic and Calimyrna.

THE CAUSE AND HISTORY OF SMUT

Examination with the microscope shows that the black mass in the inside of smutty figs is composed of a fungous growth (mycelium) and spores, resembling that which is technically called *Aspergillus niger*. This fungus is a black mold which is very common on all kinds of decaying vegetable matter. It is not a true smut like that of grain, but is given this name on account of its superficial resemblance to the latter disease. Examination of the literature shows that a similar condition in figs has been known in Europe for a long time. In 1867 Reichardt,[1] studying a fig smut apparently similar to ours, described a fungus which he named *Ustilago ficuum* as the cause of the disease. This was found in figs imported from Asia Minor into Europe. Hennings,[2] correcting the idea that this was a true smut (Ustilago), named it *Sterigmatocystis ficuum*. Wehmer[3] (p. 107), set aside the distinction between Sterigmatocystis and Aspergillus and named this fungus *A. ficuum*. A similar fungus found on dates from North Africa was first named *Ustilago phoenicis* by Corda[4] (p. 9, fig. 26) in 1840. This name was changed in 1891 to *Sterigmatocystis phoenicis* by Patouillard and Delacroix,[5] and later by Wehmer[3] to *Aspergillus phoenicis*. Von Lagerheim[6] considered this date fungus to be the same as *Aspergillus ficuum* of the fig. Thom and Currie[7] concluded that *Aspergillus niger*, as commonly understood, represents a somewhat indefinite and unstable group, containing many strains and more

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[1] Reichardt, H. W. Ein neuer Brandpilz. *In* Zool.-Bot. Ges. Wien. **17**: 335–336. 1867.

[2] Hennings, P. Ustilago Ficuum Reich. = Sterigmatocystis Ficuum (Reich.) P. Henn. *In* Hedwigia **34**: 86–87. 1895.

[3] Wehmer, C. Die Pilzgattung Aspergillus. *In* Mem. Soc. Phys. et d'Hist. Nat. Geneve **33**: (Pt. II, no. 4) 1–157, *tab. 1–5*. 1901.

[4] Corda, C. *In* Icon. Fung. **4**: 1–53, *ills.* 1840.

[5] Patouillard, M., and Delacroix, G. Sur une maladie des Dattes produite par le *Sterigmatocystis Phoenicis* (Corda) Patouill. et Delacr. *In* Bull. Soc. Myc. France **7**: 118–120, *plate IX*. 1891.

[6] Von Lagerheim, G. *In* Svensk Farmaceut. Tidskrift, no. 18, *ills.* 1903.

[7] Thom, C., and Currie, J. N. Aspergillus Niger Group. *In* Jour. Agr. Res. **7**: 1–15. 1916.

or less distinct forms. The strains which they studied as representing *A. ficuum* and *A. phoenicis* were found to be within the group and not sufficiently distinguished to be considered distinct species. They found it impossible to distinguish Sterigmatocystis as a separate genus. In California fig smut has been known for some time and the fungus so regularly associated with it has been called Sterigmatocystis or Aspergillus, without any more specific identification (Hodgson[8]).

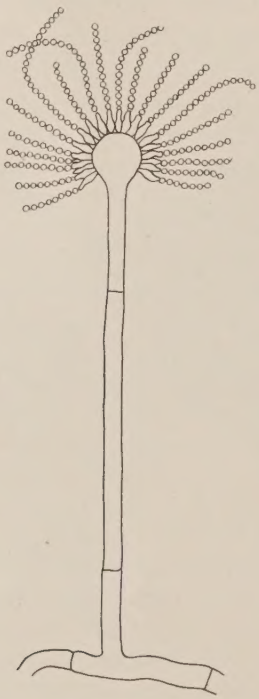

Fig. 3.—Typical spore head of a species of Aspergillus; much enlarged.

Numerous cultures and inoculations made by the writers in connection with various experiments reported in this bulletin show that a fungus of the black Aspergillus type is the specific cause of fig smut.

The question of the proper use of the names Aspergillus and Sterigmatocystis will not be considered here, but the former name will be used for our fungus and related forms. *Aspergillus niger* is one of the commonest molds occurring on decaying fruit and organic

[8] Hodgson, R. W. Black Smut of Figs. *In* Monthly Bull. Cal. State Dept. Agr. **7**: 188–189, *1 fig.* 1918.

matter in all parts of California and elsewhere (figs. 3 and 4). In considering the cause and particularly in relation to the control of fig smut, it is very important to know whether the fungus is the ordinary, universally abundant *A. niger*, or whether it may possibly be a distinct species or even strain which occurs only on the fig.

Fig. 4.—Cultures of *A. niger*, made from pulp of figs of type 5 (see p. 16). Natural size.

OPINION OF AN AUTHORITY

A culture of the fungus from a typically smutty fig was sent to Mr. Charles Thom of the United States Department of Agriculture, and the following reply received: "Your black Aspergillus has spores typical in marking and about 4 microns in diameter. There is no particular reason for separating it from the standard *Aspergillus niger*."

COMPARISON OF THE FIG SMUT FUNGUS WITH OTHER STRAINS OF ASPERGILLUS FROM THE SAN JOAQUIN VALLEY

In the district where fig smut occurs, a black mold of the same general appearance as the smut fungus is very common on all sorts of vegetable material. This is true of ripe fruit of many different kinds, decaying fruits and vegetables and the stems and leaves of plant

Fig. 5.—Smut fungus (S) as caught from air with other fungi on culture plate.

remains (fig. 6). There is also one quite definite fruit decay disease of a similar nature to fig smut. This is the so-called smut or black rot of the fruit of the pomegranate, caused by a black Aspergillus. Cultures were obtained from each of the following sources: 1. From spores floating in the air of a fig orchard, caught by exposing culture plates, Fresno, September, 1921 (see fig. 5, S). 2. From growth on

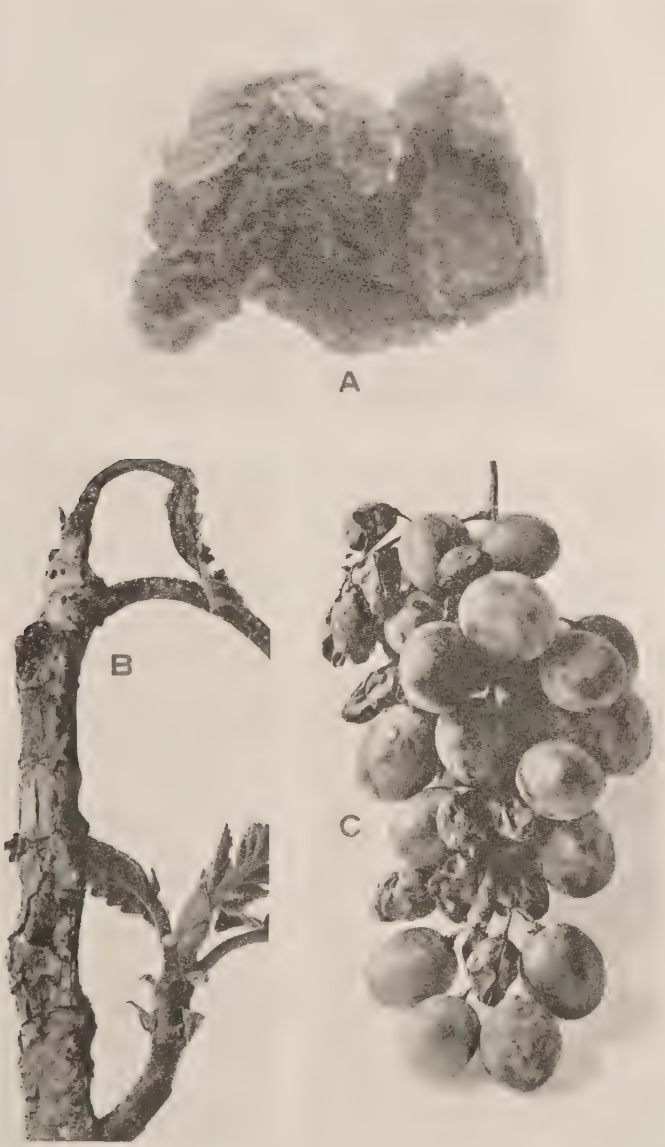

Fig. 6.—Smut fungus. (A) On apricot. (B) On fig twig. (C) On grapes.

dead fig twigs, Fresno, August, 1921 (see fig. 6, B). 3. From rotten spots on surface of fresh fig, Fresno, August, 1920. 4. Diseased dahlia stem, Fresno, 1921. 5. From inside ripe peach, Dinuba, August, 1921. 6. Ripe peach, Fresno, August, 1921. 7 Dried fig with typical smut, Fresno, September, 1921. 8. Dried raisins in cartons, Fresno, October, 1921. 9. Dry onions, Fresno, October, 1921. 10. Dry onions, Berkeley, September, 1921. 11. Pomegranate smut fungus, October, 1921. These isolations or strains were studied comparatively for the purpose of finding out whether or not the fig smut fungus is identical with the ordinary black mold, *Aspergillus niger*, which occurs so commonly on other materials.

Cultures of the eleven strains were grown under identical conditions on the following media. In this experiment the usual technical methods were employed.

(1) Czapek's agar with glucose instead of sucrose.
(2) Carrot gelatine.
(3) Prazmowski's agar.
(4) Sound Newtown Pippin apples.
(5) Nutrient gelatine.
(6) Fig agar.
(7) Raulin's solution.
(8) Hard lima bean agar.
(9) Hard potato agar.
(10) Shear's corn meal agar.
(11) Non-nutrient agar.
(12) Raw orange pulp.
(13) Raw potato slices.

A large amount of work was involved in this experiment, in preparing the various culture media and observing and recording the results in detail. For the purpose of this publication, however, it is sufficient to say that on each medium all the fungi behaved and appeared exactly alike, except number 11, the pomegranate strain, which showed a constant difference from the others. The spore stalks were taller, the spores and spore heads larger, and the spores more roughened. From the result of this experiment it appears that in its form, structure and appearance when growing on each of the media tested, the fig smut fungus cannot be distinguished from the ordinary *Aspergillus niger*, but that the form obtained from the pomegranate used in this experiment is a distinct type or species. Hodgson[5] states that "cross inoculation into pomegranates has shown that the fig Sterigmatocystis is the same as the organism causing internal rot of

pomegranates." This does not necessarily follow, however, for even though infection of the pomegranate with *Aspergillus niger* is possible, the same is true of many other fungi. Our results suggest that the pomegranate smut fungus may be a different species from that of the fig.

INOCULATIONS

For further evidence on the identity of the smut fungus, figs at different stages of ripeness were inoculated with spores from cultures of strains number 1 (from air), 2 (fig twig), 3 (fresh fig), 5 (ripe peach), 8 (raisin) and 11 (pomegranate). This and similar experiments were made and repeated many times in 1921 and 1922. In making the inoculations, a few spores were placed inside of the eye of the fig with a needle. Inoculations were made on all the common fig varieties, Calimyrna, Mission, Adriatic, and Kadota. In virtually every case, typical fungus development and smut occurred. The pomegranate fungus continued, however, to show its peculiar characteristics.

THE FIG SMUT FUNGUS IS THE COMMON *ASPERGILLUS NIGER* AND NOT A DISTINCT SPECIES

The statement by Mr. Thom and the results of comparative cultures and inoculations all indicate that the fungus which causes fig smut is not a specific strain or species of Aspergillus, but that *A. niger,* a mold which is common everywhere in the air, soil and on decaying fruit and vegetable matter of all kinds, is the usual cause of the infection.

WHEN DO FIGS BECOME INFECTED WITH SMUT

At the beginning of this investigation, little was known as to when the smut fungus infects the fig, except that some figs become infected while still on the tree. Many thought that the bulk of the infection occurred in the drying trays or even at the packing house and that some process of dipping or treatment, or quick drying at harvest time, might prevent most of the trouble.

INOCULATIONS

During the season of 1921 many experiments were made in inoculating dried, nearly dry, soft-ripe, and green figs with the fungus. It was found that Aspergillus failed to grow and no smut developed on dried or partly dried figs, but abundant fungus growth and typical smut was produced in figs by inoculations at any stage up to a time just before they commenced to soften, shrivel, and fall from the tree. It was found to be impossible to produce smut by inoculating figs after the fruit is dry enough to drop. Before the figs begin to soften they can be inoculated with the fungus and typical rot produced even when the fruit is still small and green. From these earlier inoculations it appeared therefore that smut must start at some time when the figs are still on the tree and before they commence to dry much.

The question of the time when figs naturally become infected with smut was investigated in 1921.[9] In order to systematize the work and establish a basis for reference, a series of ten types of figs was arbitrarily chosen, each type representing a stage in the ripening of the fruit. These types or stages are represented in figures 7, 8, and 9 and may be described as follows:

(1) Fruit not quite full grown, still green and hard.

(2) Full grown, eye scales beginning to loosen.

(3) Eye fairly well opened, fruit still green and firm.

(4) Slightly yielding to pressure, pulp succulent, but still firm.

(5) Fig ripe as for picking for fresh shipment. No shriveling, pulp opaque.

(6) Skin slightly shriveled, pulp somewhat translucent.

(7) Distinct shriveling, contents still red, not sticky.

(8) Much shriveled and skin beginning to discolor. Pulp mahogany color, slightly sticky.

(9) Skin brown, but flexible, pulp brown, translucent, sticky. Stage of completed normal drying.

(10) Over-dry, stiff, and hard. Flowers stand out separately in pulp.

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[9] Smith, E. H., and Phillips, E. H. Studies of the So-called "Smut" of White Fig Varieties. *In* Monthly Bull. Cal. State Dept. Agr. **11**: 755–758, *figs. 178–180.* 1922.

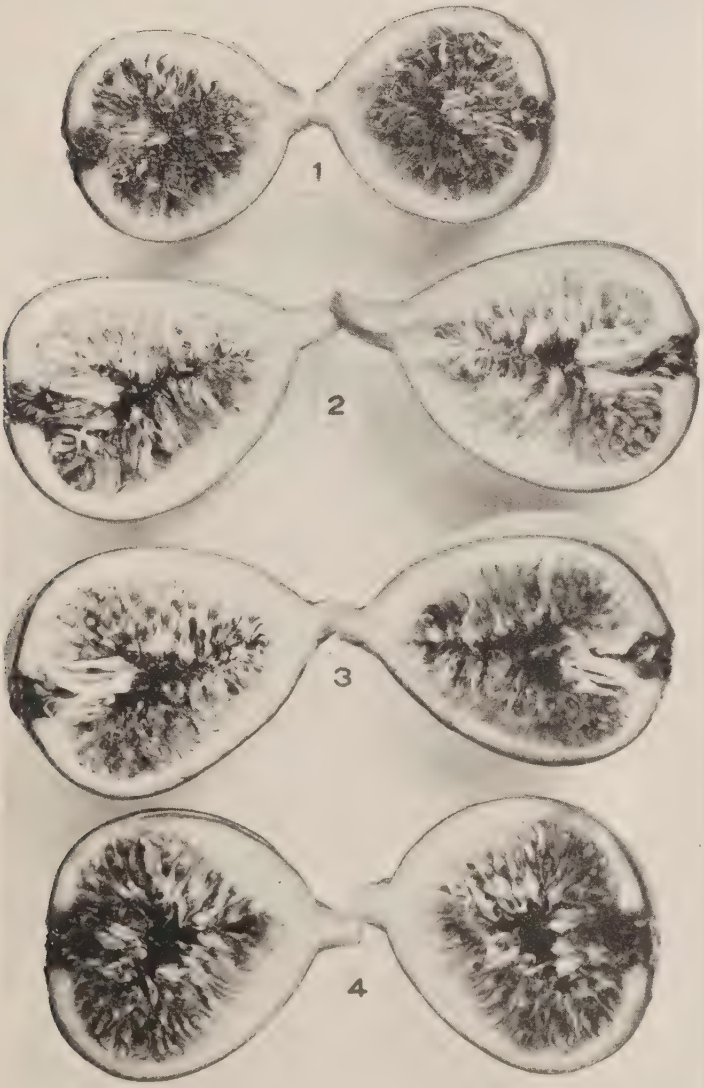

Fig. 7.—Stages of maturity in Adriatic figs, types 1, 2, 3, and 4.

As an indication of the composition of figs at these stages, especially in regard to moisture and sugar, the following analyses by the Twining Laboratory, Fresno, furnished by Mr. I. J. Condit of the Fig Growers' Association, are of interest.

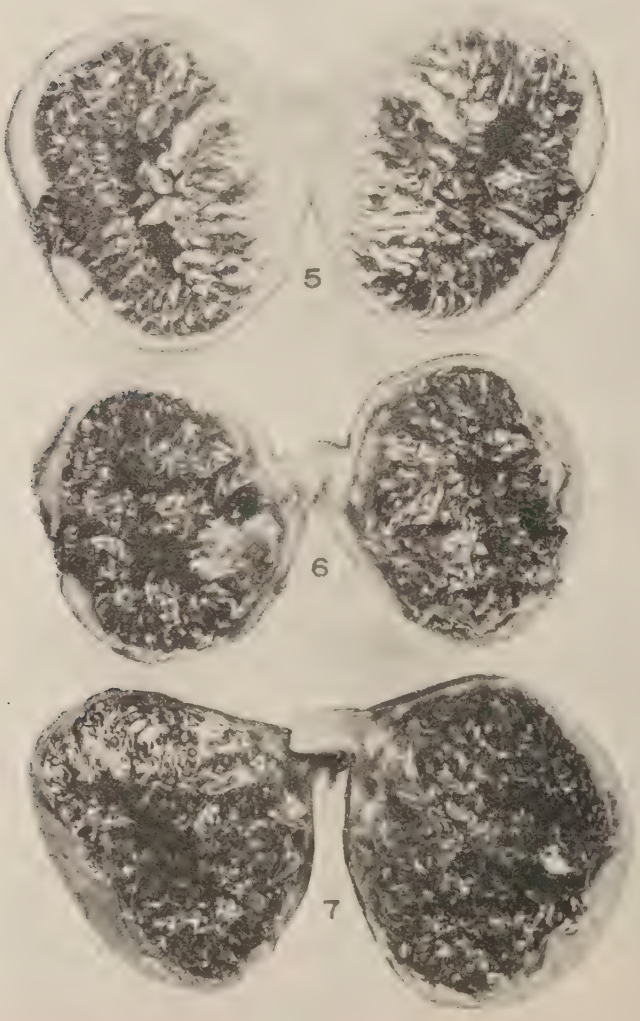

Fig. 8.—Stages of maturity in Adriatic figs, types 5, 6, and 7.

Analyses of Adriatic Figs at Different Stages of Maturity

Type	Moisture	Sugars
3	83.25%	9.12%
4	80.80%	12.92%
5	74.65%	18.87%
6	61%	33.04%
7	52.45%	46.36%
8	42.50%	46.04%
9	29%	56.85%
10	13.10%	69.58%

Fig. 9.—Stages of maturity in Adriatic figs, types 8, 9, and 10.

The increase in the percentage of sugar and corresponding decrease in moisture from type 4 to type 6 will be noticed.

All the following experiments were carried on in the vicinity of Fresno, California, under the low humidity conditions typical of the summer season in the San Joaquin Valley.

On August 18, 1921, a thick suspension in water of spores from a smutty fig was made. In this instance figs of the Kadota variety were used for inoculation. The eye of the fig to be inoculated was slightly opening by running in a glass tube drawn to a point, penetrating the fig to about one-fourth inch. A drop of the suspension was then introduced with a pipette, holding the fig a few seconds in such a way as to allow the water to run in. After the inoculations, observations were made every two days, at first by microscopic examination before the fungus became visible to the eye. Two to four figs of each type were examined at each time, four records being taken in all.

On August 31st more inoculations were made, using Adriatic, Kadota, and Calimyrna figs. Spores from pure cultures of the fungus were employed, in some cases in suspension in water, in others dry spores were inserted into the eye of the fig on the point of a sterile needle. Twenty figs or more of each kind at different stages of development were inoculated.

On September 9th, inoculations of types 6, 7, 8, and 9 were made in the laboratory because in the orchard figs of these types soon fall from the tree. The figs used were Adriatic, all picked from the tree except those of type No. 9 which had already fallen and were picked from the ground. Ten figs of each type were inoculated. Each fig was carefully split in two by cutting the skin all around up to the eye, not touching the pulp or the eye itself. Each was inoculated twice with smut spores from a pure culture, once just below the eye and again near the neck, working the spores well into the pulp with the needle. The figs were pressed together after inoculation and each fastened with a toothpick; then those of each type were placed together in moist chambers.

On September 17, 1921, ten or more Adriatic figs of types 6, 7, 8, 9, and 10 were inoculated in the laboratory. Every fig was split open and the inner surface covered with a black smear of smut spores from a pure culture. Some were pressed together again, others left open. Figs of each type were then placed in separate moist chambers.

Results were very uniform in all of these experiments. The fungus developed in green figs of any stage, producing the characteristic rot. Figs of types 2 to 5 inoculated on the tree were badly rotted within a week's time, some fruits of types 2 and 3 being almost entirely

decayed. Development was uncertain or scanty in types 7 and 8, in which drying had commenced and the sugar content high. In figs of type 8 the fungus did not develop to any great extent, and only when the fruit was kept in moist chambers and held for two or three days. In types 9 and 10, representing dried figs, there was no development whatever. These tests were probably more severe than would occur in natural infection, owing to the introduction of such large numbers of spores.

These experiments show that the rot and smut will develop if the fungous spores are introduced into figs at any time up to that when the fruit begins to dry and shrivel and is about ready to fall from the tree, but soon after it is ripe and begins to dry, the fungus is no longer able to grow upon it. This indicates that practically all smutty figs must become infected when they are still on the tree, rather than at any time after they become fully ripe and fall to the ground and that the time for any control measures would have to be before the figs ripen.

TIME OF NATURAL INFECTION

The fact that figs may be artificially infected with smut at any time before they begin to shrivel, does not necessarily indicate that natural infection takes place over the same period. If natural infection with smut occurs at any time during the early growth of the fruit, the results of our inoculation experiments would suggest that many figs would be attacked and destroyed by this fungus long before they reach maturity. This is not the case, as very few decayed or smutted figs are found except those that are virtually full grown. This indicates that the spores do not get in until the figs are nearly full grown, and consequently the smut does not start until that time. This question was studied in the following manner:

On August 22–24, 1921, twenty-eight Adriatic figs of each of the types numbered from 1 to 8 were examined by cutting them in half and studying the interior with hand lens and microscope. Smut was present in abundance in the ripe fruit on the trees from which these figs were taken. In doubtful cases, where uncertainty existed as to whether traces of smut were seen, plate cultures in fig agar were made from the suspected tissue. The result of these examinations showed that no smut, either spores or mycelium, was present in types 1 to 4 and that the interior of figs of these types was sterile. Also in type 5 no positive indications of smut were found in this experiment. In types 6 and 7 the fungus was readily detected. During the four days commencing August 29, 1921, 6355 Adriatic figs were gathered, the inside

examined by a hand lens and results checked by cultures. The findings were the same as in the last experiments, namely, that no smut fungus or any other micro-organism was found earlier than about type 5, after which stage the figs from some trees showed as high as 50 per cent infection.

On September 2, 1921, a series of cultures from the inside of Adriatic figs of the different types was started to study further the question as to when the first natural introduction of smut spores occurs. Since the previous cultures had shown that figs of the first four types contained no smut, this experiment was confined mainly to types 4, 5, and 6. The figs were cut off at the stem, carried at once to the laboratory and cultured the same day. Fig agar slants were ordinarily used. All the usual precautions were taken to avoid the possibility of smut spores being introduced into the cultures from any source other than the fig pulp to be tested. After carefully opening each fruit, a part of the pulp just below the eye, but not in contact with the surface, was cut out with a sterile needle and transferred to the culture tube. Five hundred and eight tubes from as many different figs were made in this manner, with results as before. Figure 4 shows typical cultures from the pulp of figs of type 5. Various other molds, yeasts and bacteria were also present and the abundance of these showed the same relation to maturity of the fruit as did that of the smut.

In 1922 another experiment on this point was performed in a somewhat different manner. To avoid making such large numbers of cultures, the figs were simply picked from the trees and kept for several days in a moist chamber at high summer temperature to give the smut fungus time and favorable conditions for development in any figs where it might be present. In other words the fig itself served as a culture tube. The fruit was then opened and examined. Seven hundred and thirty Adriatic figs of types 1 to 3 were used in this manner and of these only one developed the smut or any other fungus on the inside, and this was near the eye where it could have grown in from the outside. In the trees from which these figs were obtained, smut was present in considerable abundance in the mature fruit.

All the experiments show that under summer conditions in the San Joaquin Valley before the eye of the Adriatic fig opens and the fruit begins to soften the interior cavity is sterile and neither smut spores nor any other organisms enter.

IN WHAT PART OF THE FIG DOES THE INFECTION TAKE PLACE

Observation of the occurrence of smut in figs, together with the many studies and experiments described in this bulletin, leave no doubt that it is on the *inside* of the fig that infection usually occurs. Figs confined in a moist, glass chamber or dish, or simply enclosed in a cloth or paper sack on the tree, or when wet by rain, are sometimes attacked and caused to decay from the outside or at the eye by various molds. Under normal, summer conditions, however, in the interior valley, figs on the tree never show any indication of smut or mold infection on the surface, but only from the inside.

WHERE DO SMUT SPORES COME FROM

It has already been shown that the smut fungus is very common on decaying fruit of all kinds. That the spores of the fungus are also common in the air, was shown by exposing culture plates (Petri dishes with fig agar) in fig orchards in various parts of the San Joaquin Valley. Four hundred such plates were exposed, with the result that *Aspergillus niger* appeared upon most of the plates as a common mold, showing that the spores are very abundant in the air. Figure 5 shows one of these plates with Aspergillus and other molds upon it.

HOW DO SMUT SPORES GET INTO THE FIG

This is a very important consideration. The carrying agencies which suggest themselves as most probable are two, namely, air currents and insects. A third possible factor, moisture, can scarcely be considered of general importance in the interior valley, on account of the lack of precipitation during the summer.

WIND

To determine whether smut spores can be carried into figs by air currents, the following experiment was made. An Adriatic fig tree which showed no smut was chosen for inoculation. Practically every fig of types 4, 5, and 6 within reach was treated by puffing out a cloud

of spores from a smutted fig from just in front of the eye. Wind was blowing at the time and the fig was held so that the wind borne spores were carried toward the eye. Many of the eyes were black with the spores. About forty figs were thus treated and left on the tree until maturity. When examined at this time, no sign of smut was found in any of these figs. Our observations and experience in inoculating figs indicate that there is not enough moisture for the spores to commence development under the usual summer weather conditions of the valley unless they are carried well into the eye with considerable physical force and perhaps scratched into the pulp. It will be shown later, however, that if the humidity is increased, Aspergillus and other molds develop abundantly on the outer surface of the fruit and may grow through the eye into the interior.

Fig. 10.—The dried fruit beetle (*Carpophilus hemipterus*) which lives and breeds in ripening figs and is suspected of being the principal infection carrier of smut and souring.

INSECTS

The ripening fig with its almost closed interior cavity and juicy, saccharine pulp furnishes an ideal feeding and breeding place for certain insects. Flies, bees, wasps, ants, beetles, and other sugar-loving insects are attracted to the fig orchard at harvest season in great numbers. These ordinarily feed on the surface of overripe or decaying figs. Other insects seek the inner cavity of the figs, where they live and breed in the soft flesh. Decay and the souring or fermentation which occurs very commonly in ripe figs accompany such attacks so regularly that it is often thought that these insects feed only on those figs which have already started to sour or rot. When many figs are

examined, however, it is often found that the insects are present in sound fruit, and that the decay or souring develops afterward. The insects which commonly inhabit the interior of ripening figs are mainly of two species, the vinegar fly (*Drosophila ampelophaga* Loew) and the dried fruit beetle (*Carpophilus hemipterus* (Linn.)). After the ripening of the figs is well under way, it is easy to imagine that these insects must spread all forms of decay and fermentation, since they breed in great numbers in the spoiled figs, and thence enter the sound fruit and leave a trail of smut and other spores wherever they go. Pierce[10] and Hodgson[8] suggest the possibility of parasitic organisms being spread in figs by insects.

Dried Fruit Beetle.—Of these two most common species, the dried fruit beetle (figs. 10 and 14) is more especially open to suspicion. They are present from the very beginning of maturity in sound figs and their presence is always correlated with the development of the spoilage of the fruit. Howard[11] (p. 94) notes the common occurrence of this insect on figs. The vinegar fly often does not appear until the season is well advanced. The beetles crawl indiscriminately through the figs, good, smutty, or sour, spreading the organisms which cause the latter troubles. They also breed in the figs as they hang on the trees, as well as after they fall to the ground. In general, the beetle shows a more constant and earlier association with smut, souring and all the similar troubles than any other insect. In the few cases which have ever been seen of an Adriatic fig orchard where practically all the fruit was sound, no dried fruit beetles could be found. This does not in itself show whether these insects precede or are attracted by the development of spoiled fruit, but is of weight when viewed in connection with the other known facts. Another significant observation is that the time when smut spores and souring are first found in figs (about type 5, as shown in previous experiments) is the time that the eye of the fruit begins to open, the flesh softens and the beetles commence to enter. Another fact observed is that vinegar flies are not often found at all in figs of the first crop, but smut, souring, and beetles are often found in the usual correlation in this crop of figs.

It is a simple matter to prove that the dried fruit beetles in the fig orchard are carriers of smut spores, as well as of other molds, bacteria and the yeasts which accompany souring. Such organisms always develop in great abundance in cultures made from these insects, while

[10] Pierce, Newton B. Investigations of the Special Agent in California. *In* Rept. Sec. Agr. 1892: 238. 1893.

[11] Howard, L. O. Smyrna Fig Culture in the United States. *In* Yearbook U. S. Dept. Agr. 1900: 79–106., *ill.* 1901.

Fig. 11.—Building cloth tent over large fig trees to exclude insects.

beetles taken from smutty figs are covered with black spore dust visible to the naked eye. To determine whether this is the sole or principal carrier, is not so easy. The most obvious method would be to exclude these beetles from the figs in some way and observe whether smut was thereby prevented, or by eliminating all other insects except this to see if smut would still occur. The main difficulty in doing this is that almost any sort of insect-proof covering or cage increases the humidity and this produces a growth of molds on the surface of figs which may penetrate the eye. It is also necessary to enclose large numbers of figs in order to get a fair average, and this is difficult and expensive. Enclosure in paper or cloth bags causes molding of almost all of the figs and is therefore unsatisfactory.

In an attempt to accomplish the desired result, the following experiment was made in 1922. Two large Adriatic fig trees which had shown much smut the previous year in an orchard near Fresno were covered with unbleached muslin, supported on a wooden frame (see fig. 11). A cloth partition separated the two trees. The work was done very carefully in order to keep out insects. The cloth covering was put on in July about ten days before any figs of the main crop had commenced to ripen and before any dried fruit beetles appeared. The few first crop figs on these trees were removed and a very careful watch was kept throughout the experiment for the presence of insects within the cages. One hundred and twelve specimens of the dried fruit beetle, taken directly from sour and moldy figs, were liberated periodically in tent No. 2 from August 25 to October 5. Nearly all of these flew to the tops or sides of the tent as they were released and never entered the figs in the usual manner. A few were recovered from the figs picked up, but they were practically absent from the fruit and the experiment was therefore a failure in regard to testing the effect of the beetle. No vinegar flies were found in the tents at any time during the experiment and only a very few other insects, none of which would be likely to attack figs. A particular effort was made throughout the season to keep tent No. 1 free from insects of any kind. The figs in both tents were picked up and examined throughout the ripening season as fast as they fell to the ground. More than sixteen thousand figs were handled in this manner. Temperature and humidity records were taken and showed that the temperature in the tents was somewhat lower than outside and the humidity greater. Condensed moisture on the fruit and foliage was frequently noticed under the tents.

The most striking result of this experiment was that no souring occurred in either tent, although it was abundant on all the neighbor-

ing trees outside. The smut fungus, *A. niger*, was very abundant in both tents, but so far as could be determined always started on the outside or at the eye of the figs, along with many other molds. In fact, the moisture condition inside of the tent was so favorable to the growth of molds that no conclusions could be drawn as to the effect on smut of excluding insects. A fact of interest was the splitting of a large number of figs under the tent, while outside no splitting was noticed in this orchard. The experiment was not conclusive in regard

Fig. 12.—Cull oranges on ground beneath tree, furnishing ideal breeding and wintering-over place for dried fruit beetles and fungi. Photo by Condit.

to normal smut infection, but showed that enclosing the figs within the tent in some way prevented souring. The common idea that high humidity causes souring, was disproven. To carry out the original purpose of this experiment successfully, a method must be found to exclude or confine the insects at will, without changing the normal humidity, temperature, or light conditions too greatly.

Further Investigations on the Relations Between Fig Diseases and the Dried Fruit Beetle.—The indication that an important relation exists between the dried fruit beetle and the dissemination of fig smut

Fig. 13.—Old melons in field near fig orchard, furnishing abundant supply of dried fruit beetles and fungi. Photo by Condit.

and decay organisms led to further study of the habits of this insect. The beetle does not confine itself to dried fruit in the packing house, or elsewhere, but is found wherever any old fruit is allowed to accumulate, if the fruit does not become too dry. Either or both the adults or larvae of these beetles have been found in the following material at the time of year stated.

November–March—
- Figs, all kinds and conditions.
- Melons, fermenting and molding (fig. 13).
- Apples, rotting on ground.

April—
- Prunes, old, in packing house.
- Apples, in dump and under trees.
- Oranges, on ground under trees (fig. 12).
- Melons, decaying in field.

May—
- Oranges, on ground under trees.
- Figs, old culls in dry yard.

June—
- Figs, old culls in orchard.
- Oranges, on ground under trees.
- Grapefruit, culls on ground.

July—
- Figs, Cordelia variety, fresh, ripe, sound, and sour.
  - Mission, moldy, first crop on ground under tree.
  - Old culls on ground near fig orchard.
  - Brunswick variety, first crop, some sour.
  - Adriatic variety, first crop, both sound and sour.
  - Kadota variety, first crop, sour.
- Peaches, ripe, on ground.
- Apricots, ripe, rotted by smut fungus.
- Tomatoes, ripe and moldy.

August—
- Apples, rotting on ground, infested with worms, and various molds, including smut fungus.
- Melons, fermenting and moldy, smut fungus present.
- Figs, Adriatic variety, sound, souring, moldy, and smutty.
  - Kadota variety, both sound and sour.
- Peaches, fermenting and rotting, smut fungus present.
- Plums, like peaches.
- Pears, wormy, rotting, and fermenting.

September—
- Figs, Calimyrna, Kadota, and Adriatic varieties, sound, souring, rotting, moldy, and smutty, both on trees and ground.

October—
- Figs and other fruits, all kinds and conditions, many souring, moldy, and smutty.

Fig. 14.—*Carpophilus hemipterus* and other small beetles issuing from decaying orange, covered with disease germs and ready to attack first ripe figs.

In addition to its occurrence on figs and the other substances mentioned in the above list, the smut fungus, *Aspergillus niger*, was found in 1922 growing on straw, melon rinds, grapes, and on moist soil adjacent to fallen figs. All of these supported an abundant, active growth.

Blister Mite.—During the course of this work there was discovered a new species of blister mite (*Eriophyes fici* Ewing) occurring abundantly on the inside of figs of all varieties.[12] These mites are of microscopic size, being practically invisible to the eye, and cause browning of the scales and florets inside the fig. They spend the winter in the buds and enter the young figs when they are very small. No form of infection is commonly transmitted by these mites since they are present even in very small green fruit, the inside of which is sterile up to about type 4 or 5 (figs. 6 and 7) and until insects have entered. This was shown in the experiments described on page 21 in which the interior of about 8000 Adriatic figs of different stages of maturity was examined and cultured. Mites were present in virtually all of these figs. A record was kept of those which showed the most pronounced signs of mite injury, and cultures showed that there were as many sterile figs among these as in the others. Since all figs previous to type 4 were found to be sterile, and very few of types 4 and 5 developed smut or other infections, it was evident that in the figs examined, the blister mite played no important part in introducing fungous spores.

Other Insects.—In addition to the fruit beetle and vinegar fly, several insects have been found rather commonly on figs, but not with enough regularity or abundance to suggest any importance in the transmission of diseases. Small beetles, identified by Prof. E. O. Essig as *Notoxus constrictus* Casey, *Cnemoplatia sericea* Horn (fig. 15), and *Blapstinus fuliginosus* Casey, attack figs on the ground in limited numbers. Ants are common, but have never been noticed in figs on the tree.

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[12] Essig, E. O., and Smith, Elizabeth H. Two Interesting New Blister Mites. *In* Monthly Bull. Cal. State Dept. Agr. **11**: 63. 1922.
Essig, E. O. Notes on the Two New Blister Mites. *Ibid.*, **11**: 466. 1922.

CONTROL OF SMUT

SPRAYING

The possibility of controlling smut by spraying the trees, has been tested. This work has also afforded an opportunity to determine whether or not similar treatment would control other fig troubles such as souring and various forms of rot. No success whatever has been obtained by this method of treatment, as might be expected after the

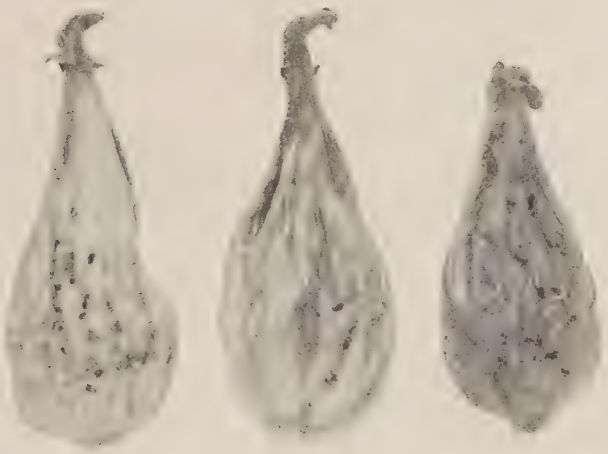

Fig. 15.—First crop Adriatic figs showing work of *Cnemeplatia sericea*, a small beetle of minor importance.

nature of these diseases and the manner in which they are introduced into the figs is understood. Pierce[10] reports similar results, and for the same reasons, in his early attempts to control fig troubles by spraying.

In 1922 B. A. Rudolph of the Division of Plant Pathology tried the applications of dormant winter sprays and also treatment just as the buds were opening in the spring. Both fungicides and insecticides were used, the latter being specially designed to control the blister mite. Spraying was done as shown in the following table in an orchard near Fresno of Adriatic figs which had shown a considerable amount of smut and a large amount of souring the previous year.

FIG SPRAYING EXPERIMENTS IN 1922

No.	Spray	Time
1	Crude Oil Emulsion 30 gals., dry lime-sulfur 48 lbs., water 170 gals.	January 19, 1922
2	Crude Oil Emulsion 30 gals., dry Bordeaux mixture 48 lbs., water 170 gals.	January 19, 1922
3	Dry Bordeaux mixture 40 lbs., water 100 gals.	January 16, 1922
4	Dry lime-sulfur 48 lbs., water 200 gals.	January 14, 1924
5	Dry lime-sulfur 24 lbs., water 200 gals.	March 25, 1922
6	Dry lime-sulfur 12 lbs., water 200 gals.	March 25, 1924
7	Dry Bordeaux mixture 32 lbs., water 200 gals.	March 25, 1924
8	1 plus 5, as above	
9	1 plus 7, as above	
10	2 plus 5, as above	
11	2 plus 7, as above	
12	3 plus 5, as above	
13	3 plus 6, as above	
14	4 plus 6, as above	

At the time when the January application was made, the leaves were all off and the trees dormant. When the spraying was done in March, the buds were just opening for the new season's growth. The table shows that some trees received the dormant spray alone, some the spring application with no other treatment, while others received combinations of the various mixtures at the two different times of application.

None of these treatments showed enough effect on the amount of smut, souring, or any other disease or pest during the following season to be considered significant. No definite counts or measurements were completed, as all the sprayed trees developed an abundance of the usual troubles.

During 1923, summer spraying was tried at various points in the San Joaquin Valley, the work being done by Messrs. J. P. Martin and P. D. Caldis of the Division of Plant Pathology in coöperation with the Fig Growers' Association and various individual growers. Blocks of trees were sprayed in sixteen different orchards located at various

points from Modesto (Stanislaus County) on the north, to Strathmore (Tulare County) on the south. In this case, all the spraying was done with the following mixture:

Dry lime-sulfur	8 lbs.
"Kayso" (Calcium caseinate)	2 lbs.
Water	200 gals.

Both Calimyrna and Adriatic figs were sprayed. Most of the spraying was done in the latter part of July just before the time when the figs reached maturity and smut, rot, and souring usually commence, and as late as it was thought possible to spray without leaving too much visible residue upon the mature fruit. No effect could be seen from any of this work, since rot, souring, and smut were present on the sprayed trees in average amounts. There was an excessive amount of spoilage in figs in 1923, so that the non-effect of the spraying was very evident.

The above described summer treatment was suggested by the success reported by some growers from such an application. It appears, however, that apparent results from spraying and other treatment of figs in controlling various forms of decay have hitherto been based upon treatment of fruit which was picked in a fresh condition, rather than that which was allowed to reach full maturity and fall to the ground for drying. When figs are picked fresh, much of the rot has only just started to develop and the fruit, therefore, appears to be free from these troubles. It is only by allowing the figs to remain on the trees until they reach full maturity that a correct estimate can be obtained.

FERTILIZATION AND SOIL TREATMENT

It has often been suggested that by keeping the soil in good condition, or by applying lime or some other chemical substance to the ground, troubles like smut and souring might be controlled. In order to test this, experiments were conducted in coöperation with the Fig Growers' Association. Nine typical fig orchards were selected in Fresno, Merced and Stanislaus counties and applications made to different blocks of trees with the following materials: lime (air slaked), 1500 lbs. per acre; sulfur, 400 lbs. per acre; horse manure, 10,000 lbs. per acre; gypsum, 1400 lbs. per acre; ammonium sulfate, 6 lbs. per tree; blood meal, 6 lbs. per tree; bean straw; nitrate of soda, 400 lbs. per acre; superphosphate, 400 lbs. per acre. The quantities stated are the maximums which were used with each substance.

Smaller quantities and various combinations of the different materials were also tried. These applications were made in the spring of 1922 and repeated on the same plots in 1923. Up to date (1924) no striking influence can be seen from the use of any of the substances tested upon the amount of smut or souring, or even upon the appearance of the trees. The gathering of exact data upon the results of these experiments has not been carried out on account of this evident lack of effect.

SANITATION

The only apparent hope of control of smut and other fig troubles due to fungi transmitted from decaying fruit by scavenger insects, lies in the elimination of such fruit and insects from the vicinity of the orchard. It is strongly recommended that all fruit, such as cull oranges and melons, should be cleaned up in the winter time, while in summer, just before the figs commence to ripen, everything that might harbor molds and fruit-decay insects should be destroyed. (See Phillips[13].)

IMMUNE VARIETIES

The fact has already been mentioned that there is a difference in the susceptibility of the different fig varieties to smut. Of the four varieties commonly grown in California, the Calimyrna and Adriatic are most susceptible, while the Black Mission and Kadota are much less commonly affected. It is significant that the same difference of susceptibility holds true in regard to souring and some of the other rots. The reason for this immunity of the Mission and Kadota was studied. First of all, it must be stated that these varieties are not entirely immune. The fact remains, however, that we seldom see them affected by *A. niger*, or any other fungus under normal summer climatic conditions in the San Joaquin Valley. Inoculations of figs of these varieties in all types were made with the smut fungus, using a pure culture from an Adriatic fig. After the inoculation, rotting took place just as in the Adriatic and Calimyrna, showing that the Mission and Kadota are not resistant to the smut fungus after it once gets in. The very solid nature of the fruit and closed eye seem to explain the immunity of these varieties. While an Adriatic fig presents a hollow, juicy interior, the fruit of the Mission and Kadota is nearly always filled out solid to the eye. The former conditions are very enticing to

[13] Phillips, Edith H. Checking Fig Smut. *In* Associated Grower 5: no. 2, 10. 1923.

insects and offer more chance even to air-borne infection; the latter conditions are unfavorable to both methods of infection. The Mission and Kadota also have a small, closed eye, making it difficult for any of the usual insects except the Blastophaga to get into the fig. Growers often say that if they had a white Mission—that is, a fig with all the other qualities of the Black Mission, but of white color—the problem would be solved. The possibility of obtaining such a variety is attractive and a start has been made in this direction. In 1921 a quantity of fig seed was gathered from Mission and Kadota trees on which the fruit had been pollinized from nearby caprifigs. This seed was planted in the spring of 1922 and a considerable number of seedlings secured. These trees, representing crosses between capri and Mission and capri and Kadota, are now being grown in orchard form to ascertain what type of fruit they will produce. In 1922 other crosses were made by hand-pollinizing Mission and Kadota with certain capris having large fleshy fruit. These capri figs were some of the so-called Maslin seedlings, which are themselves seedlings of Smyrna figs. Seedlings from these crosses are also now growing in orchard form.

CONCLUSIONS

Fig Smut is caused by the fungus *Aspergillus niger*. This is a very common mold of universal occurrence on decaying vegetable matter.

The fig smut fungus is not a special strain of *A. niger*.

Figs become infected with smut when they are still on the tree, just at the time when the eye opens and the fruit begins to soften. No infection occurs much before or after this stage.

Typical smut infection takes place on the inside of the fruit only.

In the climate of the San Joaquin Valley, the interior cavity of Adriatic figs usually remains sterile until it has been entered by insects.

The smut fungus is usually carried into figs by insects, of which the dried fruit beetle, *Carpophilus hemipterus* (Linn.) appears to be the most important.

Indications point to the dried fruit beetle as being also an important carrier of some other forms of decay. The vinegar fly (*Drosophila ampelophaga* (Loew) is probably second in importance.

The beetle lives throughout the year on various decaying fruits, which also breed vinegar flies and harbor the germs of smut and other forms of rot in figs.

Spraying, either in winter or summer, with insecticides or fungicides, had no appreciable effect in controlling smut or any other of the fig troubles observed.

Soil fertilization was also of no avail.

The destruction of the dried fruit beetle and insects of similar habits seems very promising for the control of smut.

Good orchard sanitation is the best method known at present for accomplishing this. This consists in cleaning up all old fruit, fruit culls and refuse on which such insects as the dried fruit beetle and vinegar fly might breed.

The Black Mission and Kadota varieties are much less affected by smut, souring and similar troubles than the Calimyrna and Adriatic.

This immunity of the Mission and Kadota seems to be due to the exclusion of insects from the inside of these figs by their solid structure and closed eye, rather than to any real resistance.

It may be possible to obtain a desirable, immune, white fig by breeding.

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